



Research article

Spatial Analysis of Bovine Anaplasmosis in Jambi Province, Indonesia: 2018-2022

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Abstract

Bovine anaplasmosis poses a significant economic threat in countries like Indonesia. However, in regions such as Jambi Province, where beef cattle hold a pivotal economic value, there is limited information regarding bovine anaplasmosis. This study aimed to analyze the spatial pattern and autocorrelation of bovine anaplasmosis from 2018-2022 in Jambi Province, relying on data retrieved from surveillance report. A total 5,612 blood samples from eleven districts in Jambi Provinces were subjected for *Anaplasma sp.* detection. Statistical and spatial analyses were conducted in R software v.4.3.1. The result showed that the prevalence of bovine anaplasmosis in 2018-2022 was 16.66%, with a fluctuating pattern along the year. Among the districts, Kerinci District exhibited the highest prevalence (22.26%), while Kota Jambi had the lowest (13.62%). The prevalence was significantly higher during rainy season compared to the dry season (median 18.2% vs 10.3%, respectively) ($p=0.01$). The global Moran's I indicated a random pattern of bovine anaplasmosis prevalence over the study period. However, local Moran's I indicated 17 high-high clusters, 9 high-low clusters, 12 low-high clusters, and 12 low-low clusters. In conclusion, the bovine anaplasmosis prevalence in Jambi Province fluctuated from 2018 to 2022, with a notable increase during the rainy season. Spatial analysis indicated an even distribution of the disease across the eleven districts, emphasizing the need for control and prevention strategy to mitigate bovine anaplasmosis in Jambi Province.

Keywords: *Anaplasma sp.*, Anaplasmosis, Bovine, Indonesia, Jambi, Spatial analysis

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INTRODUCTION

Bovine anaplasmosis is an important tick-borne disease caused by ricketts which commonly seen in tropical, subtropical and some temperate regions (Yang et al., 2018). Some of the well-known causative agents are *Anaplasma marginale*, *A. centrale*, *A. bovis* and *A. phagocytophylum* which are obligate intracellular bacteria. The infection caused by *A. marginale* and *A. phagocytophylum* is often followed by severe symptoms such as fever, weakness, anorexia, milk production reduction, anemia, icterus, abortion, rumen atony and sometimes caused death (Kocan et al., 2006; Dugat et al., 2015; Atif, 2016). Meanwhile, other agents such as *A. bovis* and *A. centrale* are known to cause mild or asymptomatic infection but may alter the production (Atif, 2016). Thus, bovine anaplasmosis causes a significant economic loss in many countries (Spare et al., 2020), including Indonesia. In addition, this disease is potentially distributed to other animals, such as deer (Aubry & Geale, 2011) which is widely distributed in the natural ecosystem in Indonesia and may harm the endemic animals.

In Indonesia, beef cattle are one of the biggest livestock commodities, including in Jambi Province. The population of beef cattle in Jambi is reached 160,000 approximately with a fluctuate numbers in between 2017-2022 (Badan Pusat Statistik Provinsi Jambi, 2022). The development of cattle farming in Jambi Province is hindered by cattle diseases, including bovine anaplasmosis. Previous reports have shown that the prevalence of bovine anaplasmosis in Jambi Province ranged from 23-33% (Efliana & Arianti, 2016; Susanti et al., 2019). Meanwhile, in neighboring provinces such as the Riau Islands, Riau, and West Sumatra, the prevalence ranged from 9.3 to 40.3% (Susanti et al., 2019). Effective prevention and control strategies should be applied for bovine anaplasmosis in Jambi Province. However, the insufficient information regarding the epidemiology trend of this disease in Jambi is hindered the development of prevention and control strategies. Therefore, this study aims to analyze the spatial pattern and spatial autocorrelation of bovine anaplasmosis from 2018 to 2022 in Jambi. The spatial analysis provides the information regarding disease pattern in a long period of time and can be used in predicting the disease in the future or in different region (Stevens & Pfeiffer, 2011). This technique had been used for analyzing the trend of several animal diseases such as rabies in Nepal (Shrestha et al., 2023). To the best of our knowledge, this technique was never used to analyze bovine anaplasmosis in Indonesia. The result of this study is pivotal for developing an appropriate strategy for preventing and controlling bovine anaplasmosis in Jambi Province.

MATERIALS AND METHODS

Study Location

This study uses survey data on bovine anaplasmosis in Jambi Province, Indonesia, from January 2018 to December 2022. Jambi Province is located on Sumatra Island (latitude 0°45'–2°45' S and longitude 101°10'–104°55' E), which consists of 11 districts and 144 sub-districts (BPS, 2023). As a tropical region, Indonesia has two seasons: dry and rainy. The dry season is started in

April to September, while the rainy season period is from October to March (Rahayu et al., 2018).

Ethical approval

This study used surveillance data from the Laboratory of Animal Health and Veterinary Public Health of Jambi Province reports. As no animals or animal products were directly involved in the study, ethical approval was not deemed necessary for the current study.

Data Source

Data on bovine anaplasmosis for this retrospective study were collected from the Laboratory of Animal Health and Veterinary Public Health Jambi Province, Indonesia. The data represented the outcomes of both active and passive epidemiological surveys on beef cattle from January 2018 to December 2022 in Jambi Province. Over this period, the total beef cattle population in Jambi Provinces gradually increased, rising from 159,187 individuals in 2017 to 162,002 individuals in 2022. A total of 5,612 blood samples of beef cattle were gathered across eleven districts in Jambi, namely Batang Hari, Bungo, Kerinci, Kota Jambi, Merangin, Muaro Jambi, Sarolangun, Sungai Penuh, Tanjung Jabung Barat, Tanjung Jabung Timur, and Tebo (Table 1). The detection of bovine anaplasmosis was performed using a blood smear. The datasets were compiled and categorized based on characteristics such as month and year of sampling, sampling location, sample size, and number of positive cases. All the data were compiled in Microsoft Excel 2019.

Table 1 The total bovine anaplasmosis prevalence in each district in 2018-2022 in Jambi Province.

District	Sample	Case	Prevalence (%)
Batang Hari	798	131	16.42
Bungo	663	118	17.80
Kota Jambi	580	79	13.62
Kerinci	337	75	22.26
Merangin	354	63	17.80
Muaro Jambi	683	111	16.25
Sarolangun	562	77	13.70
Sungai Penuh	89	15	16.85
Tanjung Jabung Barat	726	132	18.18
Tanjung Jabung Timur	352	63	17.90
Tebo	468	71	15.17
Total	5612	935	16.66

Data Analysis

Statistical analysis

In this study, the prevalence of bovine anaplasmosis was measured in each regional unit using a period prevalence approach each year. The period prevalence formula applied in this research is explained as follows (Thrusfield, 2018):

$$P = \frac{\text{number of individuals having a disease at a particular point in time}}{\text{number of individuals in the population at risk at that point in time}} \times 100\%$$

where P is the Prevalence. This method provides an overview of the prevalence of bovine anaplasmosis in the population in a specific period, providing a better understanding of the spread of this disease in various regional units. Statistical analysis for bovine anaplasmosis prevalence in Jambi consisted of descriptive analysis, seasonal variation, and linear regression. Descriptive analysis was used to define the trend of bovine anaplasmosis between years. In addition, linear regression was performed to assess the trend of bovine anaplasmosis prevalence from 2018-2022, with 2018 as the baseline, so that the changes of bovine anaplasmosis in each year could be defined. Seasonal analysis was assessed by comparing the prevalence in the dry and rainy season. Dry season prevalence was analyzed using data compilation from April to September, while the rainy season was defined based on the data from October to March. The normality of the data distribution was assessed using the Kolmogorov-Smirnov test and Q-Q plot. Based on the result, The Independent Samples T-test or Mann-Whitney test was performed to compare the result between seasons. Statistical analyses in this research were performed using R software version 4.3.1.

Spatial analysis

The choropleth maps and spatial autocorrelation were performed using R software version 4.3.1. The base map of Jambi province in this study was obtained from the Geospatial Indonesia portal <https://tanahair.indonesia.go.id/portal-web>. A choropleth map was used to estimate the bovine anaplasmosis burden in each district for individual years. For spatial autocorrelation, the prevalence of bovine anaplasmosis was aggregated from the study period. Two approaches were used: global autocorrelation and local autocorrelation. In global autocorrelation analysis, global Moran's I was performed to assess the spatial correlation of the whole study area following the method by (Lutfi et al., 2019; Moraga, 2023):

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n W_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=j}^n W_{ij} \sum_{i=1}^n (x_i - \bar{x})^2}$$

where I is the Global Moran's Index, n indicates locations, x_i is the value at location i , x_j is the value at location j , and \bar{x} is the mean value of the study area. Furthermore, W_{ij} denotes the elements within the standardized weight matrix between regions i and j . The Global Moran's I index value of 0 indicates that the distribution of bovine anaplasmosis exhibits a perfectly random spatial pattern. A value of +1 signifies perfect clustering, while -1 suggests a completely dispersed distribution. The significance of the Global Moran's I was determined by comparing the z-score to the standard normal distribution or via Monte Carlo randomization. Significance ($p < 0.05$) is achieved when the Z-score exceeds 1.96 or falls below -1.96 (Kumar Pant et al., 2017; Moraga, 2023). Meanwhile, the Local Indicators of Spatial Association (LISA) Moran's I was used in determining the spatial autocorrelation of each spatial unit (district) and the neighboring unit. The formula for calculating the LISA Moran's I is provided as follows (Lutfi et al., 2019; Moraga, 2023):

$$I_i = \frac{Z_i}{m_2} \sum_{j=1}^n W_{ij} Z_j$$

With:

$$Z_i = (x_i - \bar{x})$$

$$Z_j = (x_j - \bar{x})$$

$$m_2 = \sum_{i=1}^n \frac{(x_i - \bar{x})^2}{n - 1}$$

where I_i is the local Moran I Index, while Z_i and Z_j represent the deviations from the mean values. The results of local Moran's I were defined as high-high (HH), low-low (L-L), high-low (HL), and low-high (LH), which describe the correlation between one district to the neighboring district that describes the spatial pattern and the relationship in detail (Shrestha et al., 2023).

RESULTS

Descriptive analysis

The result showed that the prevalence of bovine anaplasmosis in Jambi Province, Indonesia in 2018-2022 was 16.66% (935/5,612). The annual pattern of bovine anaplasmosis in Jambi Province showed a fluctuating trend. The highest prevalence was found in 2018 with 21.52% which decreased gradually to 2020 with 10.57% but then increased again in the last two years with a prevalence of 15.67% in 2022. However, based on linear regression, no significant difference of bovine anaplasmosis prevalence was found in all years, except for 2020 prevalence compared to 2018 (-10.95*year [95% CI -20.6 to -1.32]) (p = 0.03) (Table 2). The scatterplot of linear regression for bovine anaplasmosis prevalence in Jambi Province can be seen in Figure 1A.

Table 2 The linear regression results for bovine anaplasmosis prevalence in 2018-2022 in Jambi Province.

Variable	Estimate	SE	95% CI		P-value
			Lower	Upper	
Intercept	21.52	2.79	16 to	27.03	<.00
2019 – 2018	-2.35	4.16	-10.6	5.85	0.57
2020 – 2018	-10.95	4.87	-20.6	-1.32	0.03
2021 – 2018	-3.91	4.19	-12.2	4.37	0.35
2022 – 2018	-5.85	3.81	-13.4	1.68	0.13

In seasonal analysis, the results of the Kolmogorov-Smirnov test and Q-Q plot showed that the data was not distributed normally (p = 0.01). Thus, we used the Mann-Whitney test to analyze the difference of bovine anaplasmosis between seasons. The results indicated that the prevalence of bovine anaplasmosis during the rainy season (median [range]: 18.2% [8.51-25.9%]) was significantly higher than during the dry season (median [range]: 10.3% [0-21.7%]) (p=0.01) (Figure 1B). Based on district distribution, the highest prevalence was occurred in Kerinci District (22.26%) while the lowest was found in Kota Jambi (13.62%) (Table 1).

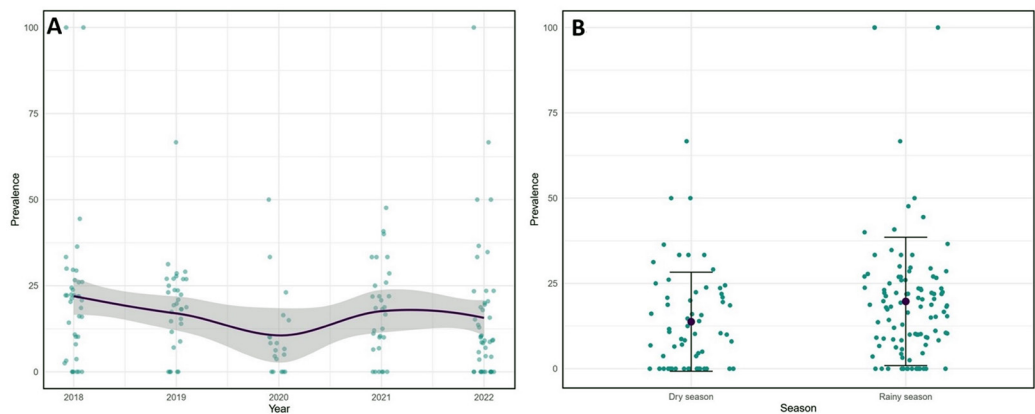


Figure 1 A. The scatterplot of linear regression for bovine anaplasmosis prevalence in Jambi Province; B. The Error bars indicate the differences between the dry and rainy seasons.

Spatial analysis

In spatial analysis, the choropleth maps indicated the similarity of bovine anaplasmosis prevalence for the overall period from 2018 to 2022. These maps suggested that the pattern of bovine anaplasmosis prevalence in individual districts of Jambi Province was changing every year. In 2018-2019, a high prevalence of bovine anaplasmosis was occurred in Kerinci District (27.4% and 28.6% respectively), but in 2020, the highest prevalence was found in Merangin District (23.8%). Meanwhile in 2021, Tanjung Jabung Barat District had the highest prevalence (30%), and in 2022, Batanghari had the highest prevalence (28.2%) (Figure 2, panel B-F).

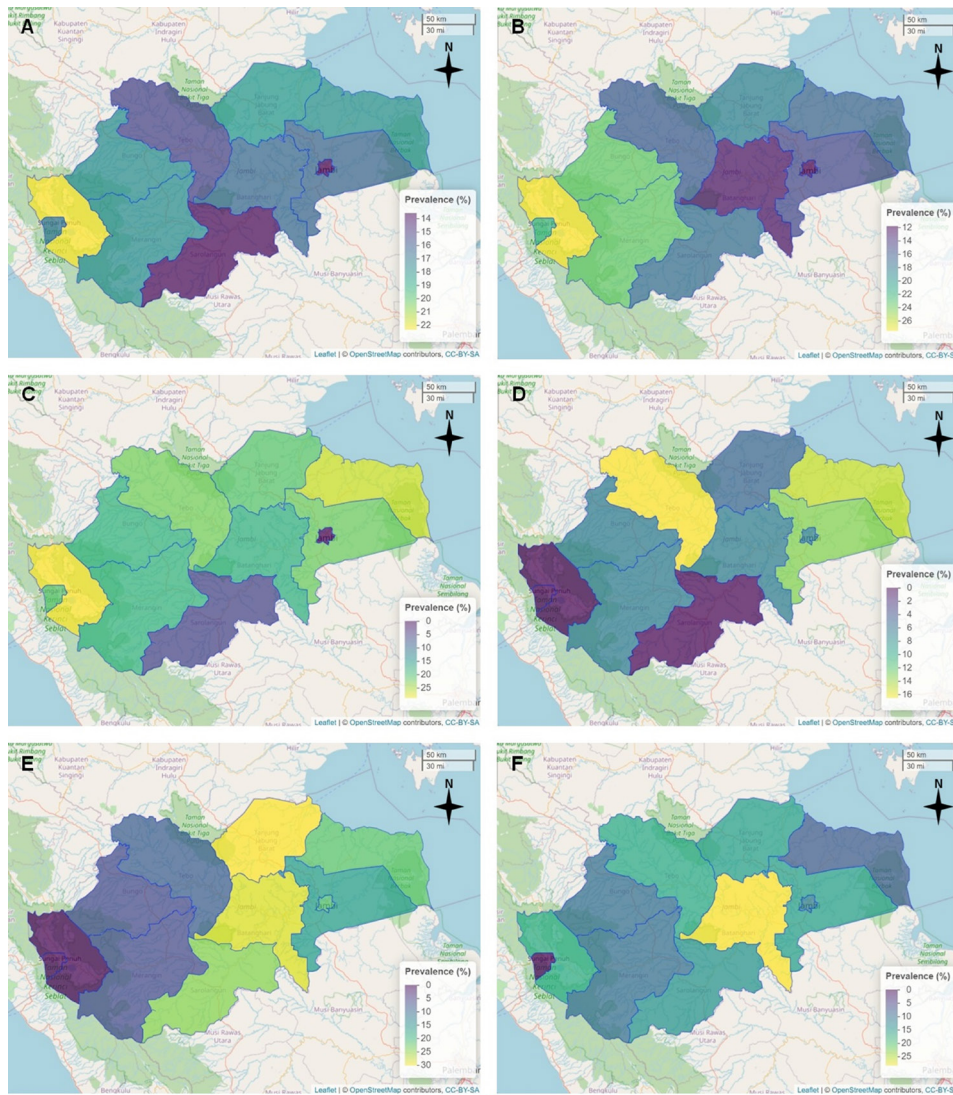


Figure 2 The choropleth map displays the annual prevalence rates of bovine anaplasmosis across various districts within Jambi Province. A. Prevalence of all years; B. Prevalence in 2018; C. Prevalence in 2019; D. Prevalence in 2020; E. Prevalence in 2021; and F. Prevalence in 2022.

To assess the spatial autocorrelation in bovine anaplasmosis prevalence across various districts, we conducted a global Moran's I analysis. The results revealed a non-significant difference in bovine anaplasmosis prevalence estimates across all years in Jambi Province (Moran's Index = 0.15, Z score = 1.16, $p = 0.12$). The global Moran's I scatterplot in this study can be seen in Figure 3. This suggested a random pattern of bovine anaplasmosis prevalence in the related districts, as indicated by the non-significant p-value and a Moran's I value close to 0. Following this result, we separated the assessment of global Moran's I into each year. The result showed that the spatial patterns in 2018 were clustered, while 2019, 2020, 2021, and 2022 were random (Table 3). The map of the local Moran's I identified 17 high-high clusters in these periods, 9 high-low clusters, 12 low-high clusters, and 12 low-low clusters throughout the survey period (Figure 4). Significantly different clusters of bovine anaplasmosis were found in 2018 and 2020 ($P < 0.05$). In 2018, significant differences were found in Kerinci (high-high) and Muaro Jambi (low-low) Districts. Moreover, in 2020, significant differences were seen in Bungo (low-high) and Merangin (low-high) District (Figure 4 & Table 4).

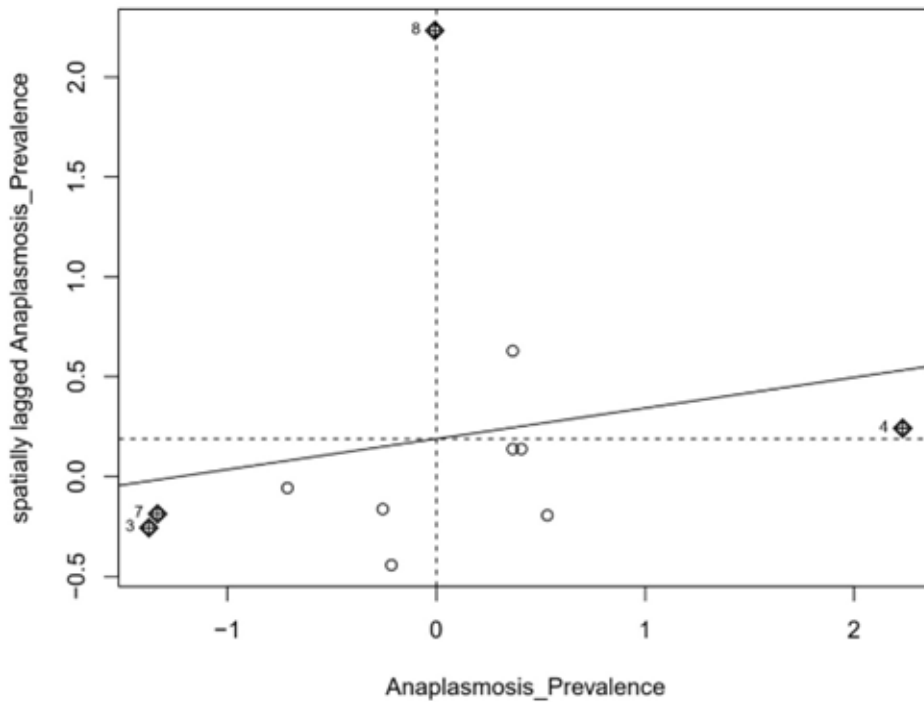


Figure 3 Global Moran's I scatterplot for prevalence of bovine anaplasmosis in Jambi Province, Indonesia.

Table 3 The Global Moran's I result for bovine anaplasmosis prevalence in 2018-2022 in Jambi Province.

Year	Moran's Index	Z Score	P-value	Spatial Pattern
2018	0.63	3.33	0.00	Clustered Pattern
2019	-0.03	0.32	0.38	Random Pattern
2020	-0.44	-1.28	0.90	Random Pattern
2021	0.17	1.26	0.10	Random Pattern
2022	-0.09	0.05	0.48	Random Pattern

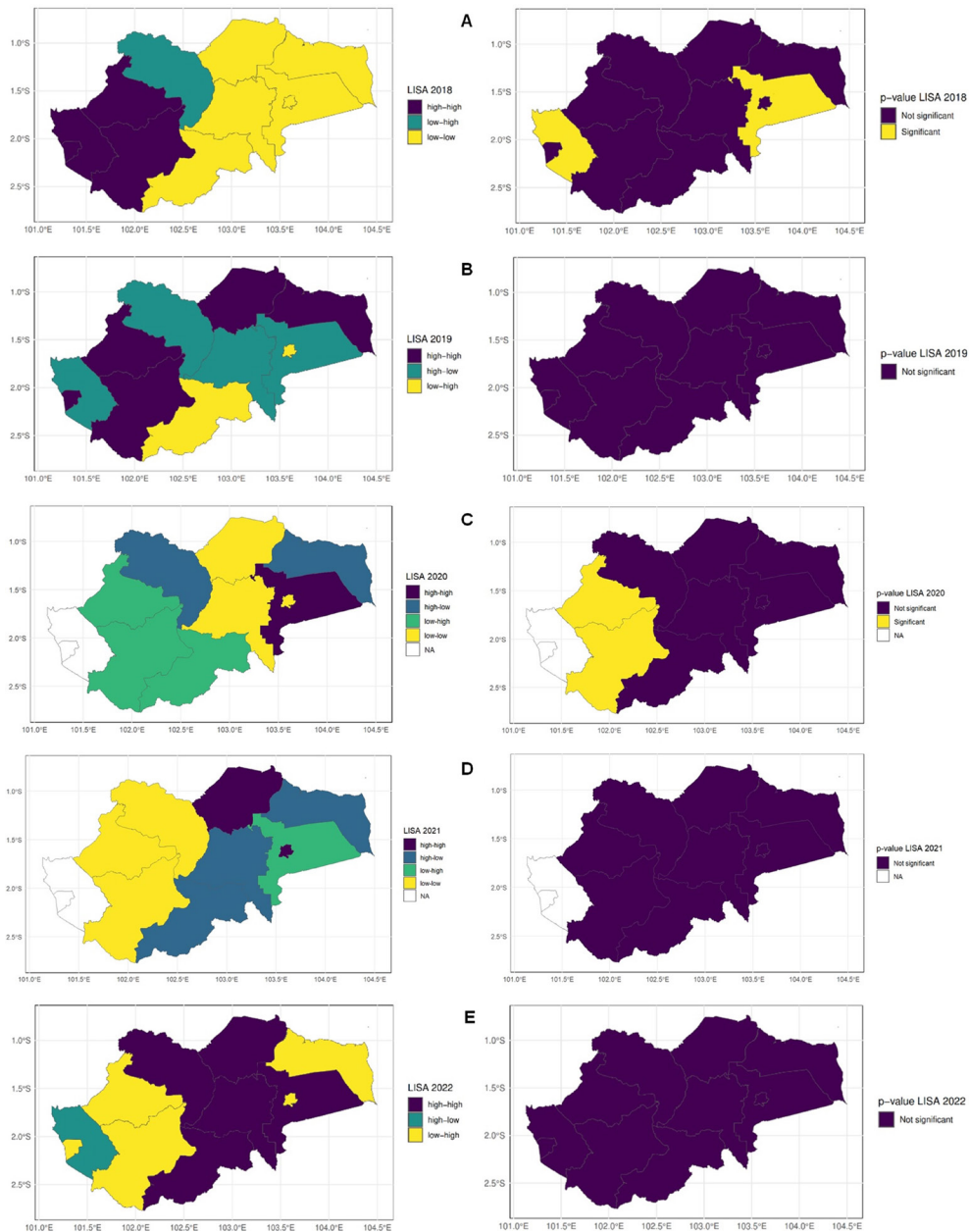


Figure 4 The LISA Moran's I for bovine anaplasmosis prevalence spanning 2018 to 2022. The left side depicts hotspots of bovine anaplasmosis prevalence, while the right side illustrates the significance of these hotspots. Panels A through E correspond to the respective years.

Table 4 The Local Moran's I for bovine anaplasmosis prevalence in every district of Jambi Province.

Year	Districts	Cluster map	Local Moran P-value
2018	Kerinci	high-high	0.00
2018	Muaro Jambi	low-low	0.04
2020	Bungo	Low-high	0.04
2020	Merangin	Low-high	0.04

DISCUSSION

The result of our study showed that the prevalence of bovine anaplasmosis in Jambi Province from 2018 to 2022 was 16.66%, lower than previous reports of bovine anaplasmosis in Jambi Province (Efliana and Arianti, 2016; Susanti et al., 2019). It indicates that the prevalence of bovine anaplasmosis in Jambi Province has fluctuated from time to time. The result of our study is within the range of bovine anaplasmosis of other neighboring regions which suggests that the bovine anaplasmosis in Jambi Province and other provinces in Sumatra Island is similar (Susanti et al., 2019). In another region of Indonesia, the prevalence of bovine anaplasmosis was reported to be 11% in Sumbawa, West Nusa Tenggara (Anggraini et al., 2019), 40% in Tangerang, West Java (Aminah et al., 2022), and 41% in Banyuwangi, East Java (Haryuningtyas and Wardhana, 2020). On the contrary, some regions such as Yogyakarta provinces, Surabaya City, and Sidoarjo District show less than 1% bovine anaplasmosis prevalence (Dewi et al., 2018; Dyahningrum et al., 2019).

The diversity of bovine anaplasmosis prevalence between regions also shown in other country, such as Iran with a prevalence range from 0-37.3% in different regions (Noaman and Bastani, 2016; Mohammadian et al., 2021). In other countries, such as Sudan, bovine anaplasmosis prevalence can be relatively low at 13.2% (Eisawi et al., 2020) but can be up to 66% in some regions (Rahman, 2013). Similarly, in Pakistan the prevalence of bovine anaplasmosis ranging from 4-72.9% which suggested related to the difference in geo-climatic condition which play a role in tick population and propagation (Sajid et al., 2009; Sajid et al., 2014; Farooqi et al., 2018). In our study, the prevalence of bovine anaplasmosis in all studied districts in Jambi Province was not significantly different throughout study period. In all eleven studied districts in Jambi Province, the geo-climatic condition is similar, thus the prevalence of the bovine anaplasmosis is also similar in all districts which can be seen based on the global and local Moran's I. A significantly different pattern between districts was only seen in 4 districts within 5 years, indicating most of the districts has similar prevalence of bovine anaplasmosis during the study period.

A significant difference of bovine anaplasmosis prevalence in Jambi Province was found between seasons. The rainy season has a higher prevalence of bovine anaplasmosis which is suggested due to the higher prevalence of tick as its vector. Tick such as *Rhipicephalus sp.* is a well-known vector of bovine anaplasmosis and its presence is significantly related to the *Anaplasma sp.* prevalence (Abdela et al., 2018). In Indonesia, *R. microplus* is one of the most common ectoparasites in cattle (Sahara et al., 2019). The presence of *Rhipicephalus sp.* is found to be more prevalent in the rainy season in which the humidity level is relatively high (Shoaib et al., 2022; Mohamed et al., 2023). In our result, the prevalence of bovine anaplasmosis is found to be higher in the rainy season which may related to the prevalent prevalence of the tick as its vector.

Some limitations are present in the current study. Our study focuses on using a retrospective data from bovine anaplasmosis in Jambi Province in the period of 2018-2022. However, the number of samples in each year varies, especially in 2020 when the sample collection is limited to a 6-month period

due to COVID-19 movement restrictions. Even though there is variation in the sample number, the results of our study can represent the bovine anaplasmosis prevalence in Jambi Province and its distribution on eleven districts in Jambi Province. A relatively similar prevalence of bovine anaplasmosis in all studied districts in Jambi Province indicates an equal distribution of this disease across all districts.

CONCLUSIONS

In conclusion, the bovine anaplasmosis prevalence in Jambi Province from 2018-2022 was found 16.66% with a variation between years and seasons. The similarity of bovine anaplasmosis spatial pattern among districts in Jambi Province suggested an equal distribution of the disease. Further study on identification of *Anaplasma* species and modeling study to predict bovine anaplasmosis prevalence in Jambi Province should be conducted. Furthermore, an appropriate control and prevention strategy should be performed to reduce the prevalence of bovine anaplasmosis. Tick control and vaccination are suggested as prevention program.

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AUTHOR CONTRIBUTIONS

Sarwo Edy Wibowo: Conceptualization, Methodology, Project Administration, Sample collection, Original Draft Preparation.

Morsid Andityas: Conceptualization, Methodology, Data analysis, Visualization, Draft Review and Editing.

Dian Meididewi Nuraini: Conceptualization, Methodology, Analyzed the data, Visualization, Original Draft Preparation, Review and Editing, Supervision.

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Aan Awaludin: Conceptualization, Methodology, Review and Editing.

Pudji Rahayu: Conceptualization, Methodology, Sample collection, Project Administration, Review and Editing.

CONFLICT OF INTEREST

All authors have no conflicts of interest.

REFERENCES

- Abdela, N., Ibrahim, N., Begna, F., 2018. Prevalence, risk factors and vectors identification of bovine anaplasmosis and babesiosis in and around Jimma town, Southwestern Ethiopia. *Acta. Trop.* 177, 9–18.
- Aminah, A., Setiani, R.I., Ekawasti, F., 2022. Identifikasi endoparasit pada sapi brahman cross (BX) di Rumah Potong Hewan (RPH) Kota Tangerang. *Acta Vet. Indones.* 2022, 41–48.
- Anggraini, M., Primarizky, H., Suwanti, L.T., Hastutiek, P., Koesdarto, S., 2019. Prevalence of blood protozoa disease on cattle and buffalo in Moyo Hilir Sub-District, Sumbawa District West Nusa Tenggara. *JoPS*, 3(1), 9–14.
- Atif, F.A., 2016. Alpha proteobacteria of genus *Anaplasma* (Rickettsiales: Anaplasmataceae): Epidemiology and characteristics of *Anaplasma* species related to veterinary and public health importance. *Parasitology*. 143(6), 659–685.
- Aubry, P., Geale, D.W., 2011. A review of bovine anaplasmosis. *Transbound. Emerg. Dis.* 58(1), 1–30.
- Badan Pusat Statistik Provinsi Jambi., 2022. Populasi Ternak Besar Kab-Kota (Ekor), 2019-2021. Available online: <https://jambi.bps.go.id/indicator/24/66/1/populasi-ternak-besar-kab-kota.html> (Accessed on July 26, 2023).
- BPS, 2023. Jumlah Kecamatan (Tahun), 2020-2022. Badan Pusat Statistik Provinsi Jambi. Available online: <https://jambi.bps.go.id/indicator/153/1188/1/jumlah-kecamatan-.html> (Accessed on August 5, 2023).
- Dewi, A.P., Khadjadaton, Rochmadiyanto, Imran, K., 2018. Penyebaran Penyakit parasit darah pada sapi dan kerbau di wilayah kerja BBVET Wates tahun 2017. Prosiding Penyidikan Penyakit Hewan Rapat Teknis dan Pertemuan Ilmiah (RATEKPIL) dan Surveilans Kesehatan Hewan Tahun. 375–381.
- Dugat, T., Lagrée, A.C., Maillard, R., Boulouis, H.J., Haddad, N., 2015. Opening the black box of *Anaplasma phagocytophilum* diversity: current situation and future perspectives. *Front. Cell. Infect. Microbiol.* 5, 61.
- Dyahningrum, D.M., Mufasirin, M., Harijani, N., Hastutiek, P., Koesdarto, S., Yunus, M., 2019. Identification of blood parasite on sacrificial cattle slaughtered during Idul Adha 1438 H in Surabaya City and Sidoarjo Regency. *JoPS*. 3(2), 77.
- Efliana, Arianti, N., 2016. Survey penyakit parasit darah pada sapi di UPT Peternakan dan Puskesmas Wilayah II Kabupaten Lima Puluh Kota. *Buletin Informasi Kesehatan Hewan*. 18(93), 35–42.
- Eisawi, N.M., El Hussein, A.R.M., Hassan, D.A., Musa, A.B., Hussien, M.O., Enan, K.A., Bakheit, M.A., 2020. A molecular prevalence survey on *Anaplasma* infection among domestic ruminants in Khartoum State, Sudan. *Trop. Anim. Health Prod.* 52(4), 1845–1852.
- Farooqi, S.H., Ijaz, M., Rashid, M.I., Nabi, H., Islam, S., Aqib, A.I., Hussain, K., Khan, A., Rizvi, S.N.B., Mahmood, S., Mehmood, K., Zhang, H., 2018. Molecular epidemiology of bovine anaplasmosis in Khyber Pakhtunkhwa, Pakistan. *Trop. Anim. Health Prod.* 50(7), 1591–1598.
- Haryuningtyas, D., Wardhana, A.H., 2020. Deteksi anaplasmosis pada sapi dan kerbau di banyuwangi dengan ulas darah tipis dan polymerase chain reaction. In *Prosiding Seminar Nasional Teknologi Peternakan Dan Veteriner*, 26-27 October 2020, pp. 301–314.
- Kocan, K.M., Blouin, E.F., Barbet, A.F., 2006. Anaplasmosis control: past, present, and future. *Ann. N. Y. Acad. Sci.* 916(1), 501–509.
- Kumar Pant, D., Tenzin, T., Chand, R., Kumar Sharma, B., Raj Bist, P., 2017. Spatio-temporal epidemiology of Japanese encephalitis in Nepal, 2007-2015. *PLoS One*. 12(7), e0180591.
- Lutfi, A., Aidid, M.K., Sudarmin, S., 2019. Identifikasi Autokorelasi spasial angka partisipasi sekolah di Provinsi Sulawesi Selatan menggunakan indeks Moran. *VARIANSI: J. Stat. App. Teach. Res.* 1(2), 1–8.
- Mohamed, A., Fedlu, M., Nigussie, T., Wali, M.A., 2023. Prevalence, seasonal dynamics and associated variables of ixodid tick cattle infestation in Gondar, northwestern Ethiopia. *Parasite Epidemiol. Control.* 21, e00294.

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- Mohammadian, B., Noaman, V., Emami, S.J., 2021. Molecular survey on prevalence and risk factors of *Anaplasma* spp. infection in cattle and sheep in West of Iran. *Trop. Anim. Health Prod.* 53(2), 1–7.
- Moraga, P., 2023. Spatial statistics for data science: theory and practice with R. Chapman & Hall/CRC. Available online: <https://www.paulamoraga.com/book-spatial/spatial-autocorrelation.html> (Accessed on August 5, 2023).
- Noaman, V., Bastani, D., 2016. Molecular study on infection rates of *Anaplasma ovis* and *Anaplasma marginale* in sheep and cattle in West-Azerbaijan province, Iran. *Vet. Res. Forum.* 7(2), 163.
- Rahayu, N.D., Sasmito, B., Bashit, N., 2018. Analisis pengaruh fenomena indian ocean dipole (iod) terhadap curah hujan di Pulau Jawa. *JGUndip.* 7(1), 57–67.
- Rahman, A., 2013. Some epidemiological aspects of bovine anaplasmosis in South Kordofan State, Sudan. *Sudan J. Vet. Res.* 29–35.
- Sahara, A., Nugraheni, Y.R., Patra, G., Prastowo, J., Priyowidodo, D., 2019. Ticks (Acari: Ixodidae) infestation on cattle in various regions in Indonesia. *Vet. World.* 12(11), 1755–1759.
- Sajid, M.S., Iqbal, Z., Khan, M.N., Muhammad, G., Khan, M.K., 2009. Prevalence and associated risk factors for bovine tick infestation in two districts of lower Punjab, Pakistan. *Prev. Vet. Med.* 92(4), 386–391.
- Sajid, M.S., Siddique, R.M., Khan, S.A., Iqbal, Z., Khan, M.N., 2014. Prevalence and risk factors of anaplasmosis in cattle and buffalo populations of district Khanewal, Punjab, Pakistan. *Glob. Vet.* 12(1), 146–153.
- Shoaib, M., Rashid, I., Akbar, H., Sheikh, A.A., Farooqi, S.H., Khan, M.A., Mahmood, S., Khan, F.A., 2022. Prevalence of ixodidae ticks and their association with different risk factors in Khyber Pakhtunkhwa, Pakistan. *J. Anim. Plant. Sci.* 32(2), 413–420.
- Shrestha, S.P., Chaisowwong, W., Arjkumpa, O., Upadhyaya, M., Koirala, P., Maharjan, M., Shrestha, S.P., Punyapornwithaya, V., 2023. Temporal trend and high-risk areas of rabies occurrences in animals in Nepal from 2005 to 2018. *Vet. Integr. Sci.* 21(2), 411–427.
- Spare, M.R., Hanzlicek, G.A., Wootten, K.L., Anderson, G.A., Thomson, D.U., Sanderson, M.W., Ganta, R.R., Reif, K.E., Raghavan, R.K., 2020. Bovine anaplasmosis herd prevalence and management practices as risk-factors associated with herd disease status. *Vet. Parasitol.* 277, 100021.
- Stevens, K.B., Pfeiffer, D.U., 2011. Spatial modelling of disease using data- and knowledge-driven approaches. *Spat. Spatiotemporal. Epidemiol.* 2(3), 125–133.
- Susanti, T., Hartini, R., Santosa, B., 2019. Parasit Darah dan Profil Hematologinya Secara Kualitatif pada Sapi di Wilayah Reginal BVet Bukittinggi Tahun 2018. *Buletin. Informasi. Kesehatan. Hewan.* 21(98), 29–34.
- Yang, J., Han, R., Niu, Q., Liu, Z., Guan, G., Liu, G., Luo, J., Yin, H., 2018. Occurrence of four *Anaplasma* species with veterinary and public health significance in sheep, northwestern China. *Ticks. Tick. Borne. Dis.* 9(1), 82–85.
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